# CSC148, Assignment #2
# Regular expressions
# due 11:55pm March 27, 2016

## Introduction

Regular expressions (abbreviated to *regex*, the pronunciation of which gives rise to endless flame wars...) are used in various programming languages and utilities to match entire classes of strings. This assignment will give you experience modelling a regular expression as a tree, and detecting which strings match a given regular expression.

We won't favour any particular regex language or utility, such as Python, Java, or Linux's grep, but use a stripped-down simplified regular expression form that contains all the essential principles. In particular, you are **not** permitted to import Python's regular expression module `re` into any file you submit.

We'll only be dealing with a ternary alphabet, i.e., $\{0, 1, 2\}$. Generalizing to an arbitrary alphabet is straightforward, but doesn't buy us much for the purpose of this assignment. The elementary regex symbols we'll use can be easily typed in Python source code. A regex (over ternary alphabet $\{0, 1, 2\}$) is a nonempty string made up of the following symbols.

`'0'` called zero

`'1'` one

`'2'` two

`'e'` pronounced "ee" or "epsilon"

`'|'` bar

`'.'` dot

`'*'` star

`'('` left parenthesis, or left

`')'` right parenthesis, or right

There are several rules determining that a string made up of these symbols is a valid regular expression:

1. There are 4 regexes of length one. They are:
   - '0'
   - '1'
   - '2'
   - 'e'
2. If $r$ is a regular expression, then so is $r$ + '*', where the plus symbol '+' means string concatenation, as in Python.
3. If $r_1$ and $r_2$ are regexes, then so are:
   - '(' + $r_1$ + '|' + $r_2$ + ')'
   - '(' + $r_1$ + '.' + $r_2$ + ')'

Here are some examples of regexes:

- '0'
- '1'
- '2'
- 'e'
- '0*'
- '1*'
- '2*'
- 'e*'
- '(0|1)'
- '(1.2)'
- '(e|0)'
- '(2.e)'
- '(0*|2*)'
- '((0.1).2)'
- '((1.(0|2)*).0)'

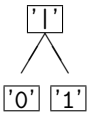
## Tree Representation of Regexes

Every regex can be (uniquely) represented as a tree. Each leaf node contains exactly one of '0', '1', '2', or 'e'. Each internal node contains exactly one of '.', '|', or '*'.

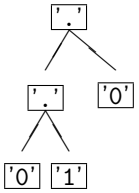
A regex of length one is represented by a tree of one node containing the symbol in the regex. For example, the regex '0' is represented by the tree whose root is the leaf node containing '0'.

A regex of the form $r$ + '*' is represented by a tree whose root node contains '*', and that node has one child which is the tree that represents the regex $r$. E.g., the regex '1*' is represented by the following tree:

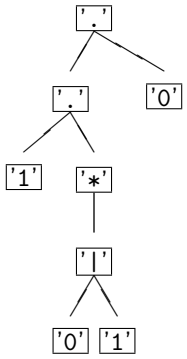

A regex of the form '(' + $r_1$ + '|' + $r_2$ + ')' is represented by a tree whose root node contains '|', and that node has left and right children which are the trees that represent the regexes $r_1$ and $r_2$ respectively. For example, the regex '(0|1)' is represented by the following tree:




A regex of the form '(' + $r_1$ + '.' + $r_2$ + ')' is represented just as a regex of the form '(' + $r_1$ + '|' + $r_2$ + ')', except the root now contains '.' rather than '|'. For example, the regex '((0.1).0)' is represented by the following tree:




Here's an example that combines all concepts from above. The regex '((1.(0|1)*).0)' is represented by the following tree:



## Matching Strings with Regexes

A ternary string is a string (possibly empty) that contains only the symbols '0', '1' and '2'. For a regex $r$ and a ternary string $s$, we define below what it means for $r$ to match $s$. (Equivalently we may also say that $s$ matches $r$, or that $r$ and $s$ match).

1. A regex of length one matches exactly one string. Specifically:
   - the regex '0' matches the string '0'
   - the regex '1' matches the string '1'
   - the regex '2' matches the string '2'
   - the regex 'e' matches the string '' (i.e., 'e' matches the empty string)
2. A regex of the form $r$ + '*' matches string $s$ if and only if either
   (a) $s$ equals '' (empty string), or
   (b) $s$ has the form $s_1 + s_2 + \cdots + s_k$ where $k > 0$ and $r$ matches every $s_i$

   For example, the regex '0*' matches any string (possibly empty) that contains no other symbols than the symbol '0'
3. A regex of the form '(' + $r_1$ + '|' + $r_2$ + ')' matches string $s$ if and only if:
   (a) $r_1$ matches $s$, or
   (b) $r_2$ matches $s$, or
   (c) both of the above

   For example, the regex '(2|0*)' matches the string '2' as well as any string that contains only the symbol '0'
4. A regex of the form '(' + $r_1$ + '.' + $r_2$ + ')' matches a string $s$ if and only if there are two strings $s_1$ and $s_2$ (each possibly empty) such that
   (a) $s$ is the concatenation of $s_1$ and $s_2$ (i.e., $s$ equals $s_1 + s_2$), and
   (b) $r_1$ matches $s_1$, and
   (c) $r_2$ matches $s_2$.

   For example, the regex '(1*.2)' matches any string that contains zero or more '1's, followed by exactly one '2'.

Here's an example that combines all concepts from above. The regex '((1.(0|1)*).2)' matches any string that starts with '1' and ends with '2', and has any number of '0's and '1's in between (including nothing in between).

## Your Job

**Stage 1:** Design a collection of classes to represent the various sorts of regular expression trees. Each class should implement or inherit at least the following methods: `__init__` , `__eq__` and a `__repr__`. `__repr__` should be written in such a way that it will allow you copy its output into a Python shell to produce an equivalent tree. You should carefully consider how to use inheritance to reduce the amount of duplicated code. You should also ensure that public attributes for a tree's symbol or children can only be set once, during initialization (i.e., they should be private, and have not be set in any method other than `__init__`).

Your classes should be written in a file called **regex_design.py**.

**Stage 2:** You should:

1. Download `regextree.py` and `regex_functions.py` Add your name to the license at the top of **regex_functions.py**, indicating that you have added intellectual value to it. However, do not add any import statements, or change the import statement, in **regex_functions.py**. You may only distribute the files, or modified versions of them, with the same license, and along with the file COPYING
2. In **regex_functions.py** implement the following module-level functions:

   **is_regex(s):** which takes a string **s** and produces **True** if it is a valid regular expression (according to the characterization in the introduction of this handout), but **False** otherwise.

   **all_regex_permutations(s):** which takes a string **s** and produces the set of permutations of **s** that are valid regular expressions (according to the characterization in the introduction of this handout)

   **regex_match(r, s):** which returns **True** if and only if string **s** matches the regular expression tree rooted at **r**.

   **build_regex_tree(regex):** which takes a valid regular expression string **regex**, builds the corresponding regular expression tree, and returns its root.
3. Submit **regex_functions.py** on MarkUs[1]

[1] Wait a second... what about all the work I did in `regex_design.py`? That was what we call a *planning document*. The goal there is to compare your own design with ours, and see if you can figure out why we made the design decisions that we made. You don't have to hand it in, but it's a good exercise. Also, if you're really upset and feel it's unfair to waste your time designing something you don't need to hand in, then it's okay, because you read through the entire handout first and saw this footnote before you wrote anything anyway, right?